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Advantages and Application Paths of BIM5D Technology in Cost Control of Completed Houses

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Abstract: The purpose of this article is to analyze the advantages and application paths of BIM5D technology in the cost control of completed houses. In the research phase, based on the reading of literature and the combination of project materials, the advantages of BIM5D in the cost control project of completed houses are analyzed after introducing the cost control of completed houses and the connotation of BIM5D technology. Finally, this article starts from multiple perspectives, including BIM5D modeling, cost deviation analysis under dynamic cost control, etc., and finally forms a relatively systematic and complete BIM cost control technology system. It is hoped that this article can provide technical reference value for China's completed housing projects, promote the improvement of the project team's cost control level, obtain considerable economic benefits based on completing project construction with quality and quantity, and enhance the competitiveness of enterprises.

Keywords: BIM5D; Cost deviation; Cost performance; Schedule performance

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1. Introduction

Unlike rough houses, the cost control content designed for finished houses is more complex, incorporating various costs in the process of house decoration. The difficulty of cost control is much higher than that of traditional rough houses. It also involves the cost of household appliances and furniture configuration. Therefore, to achieve cost control of finished housing projects, construction engineering enterprises have begun to explore how to promote the deep implementation of cost management based on digitization [1]. BIM, as a widely implemented and applied modeling technology in the field of construction engineering in recent years, has the capabilities of visualization and data analysis, effectively solving the problem of human data analysis errors and enabling the entire process tracking of projects. Therefore, research on cost control of finished houses based on the BIM5D model is of great significance to the cost management level of construction engineering enterprises and the future industrial development.

2. Overview of cost control for finished houses and BIM technology

2.1. Cost control for finished houses

Cost control for finished houses refers to the systematic management of costs through scientific management and

monitoring means throughout the entire lifecycle of building construction, ensuring that the project progresses smoothly and is constructed within the budget [2]. Typically, the cost control process for finished houses covers various aspects such as budget preparation, cost prediction, cost tracking, cost analysis, and later cost evaluation. The difference in cost management between finished and rough houses lies in the fact that, besides considering the basic construction costs of houses (common building materials, construction equipment, human resources), finished houses also need to consider the management of renovation expenses (including household appliance expenses).

2.2. BIM5D technology

BIM5D refers to the establishment of a traditional BIM-3D model based on BIM building information modeling, combined with the integration of construction progress and cost information to form a 5D multidimensional model. During the project implementation phase, the BIM-3D model is mainly responsible for providing geometric information and spatial relationships of building components, while the BIM-5D model is a further extension of the 3D model, integrating project time dimension and economic dimension data into the model, making the construction management process more comprehensive and visual. The integration of cost information can help the project team achieve real-time monitoring of the difference between the project budget and actual expenditure. This process can be applied throughout the entire lifecycle of the construction project, further enhancing the level of cost control [3].

3. Technical advantages of BIM5D technology in cost control of finished houses

3.1. Visual cost management

In finished housing projects, the visual cost management of BIM5D technology transforms traditional 2D drawings into dynamic 3D models, making the cost distribution more intuitive. Through immersive visual displays, project participants can precisely locate high-cost areas and potential waste points. Compared to rough houses, finished houses involve a lot of fine decoration and high-quality requirements. The visual management function provided by BIM5D allows more precise cost control during the design and construction phases, reducing financial risks caused by design changes [4].

3.2. Real-time data analysis and integration

During the development process of finished houses, the real-time data analysis and integration function of BIM5D technology allows project managers to keep abreast of dynamic cost changes. Since finished houses emphasize the coordination of progress and quality, real-time data analysis ensures the timeliness and accuracy of information, thereby guaranteeing timely and effective decision-making during the construction process.

3.3. Risk proactive identification

BIM5D technology can enhance the proactive identification of cost risks in finished houses. By predicting construction progress, cost, and material selection data through the 5D model, BIM can help project teams identify potential cost overrun risks early. This proactive identification can avoid quality non-compliance and budget overruns in the context of high-quality requirements for finished houses, allowing for early optimization of various resource allocations such as personnel, materials, and equipment, and avoiding potential risks [5].

4. Application paths of BIM5D technology in cost control of finished houses

4.1. Project overview

The Qinghe Jincheng finished housing community project is located on Xueyuan West Road, Tengzhou City, Zaozhuang City, Shandong Province. Its 1# – 6# and 8# buildings have a total above-ground floor area of 52,176 m^2 and an underground area of 32,950 m^2. The 7# building has a total construction area of 9,239 m^2 and is equipped with 72 residential units. During the project development stage, the developer and project team attached great importance to effective cost control. BIM building information modeling technology was introduced during the construction phase, and a BIM platform was established for participating units to manage construction quality, progress, and cost.

4.2. Design of construction cost control model for finished houses

4.2.1. Modeling process

During the construction phase of the Qinghe Jincheng finished housing community project, the project teams modeling of the cost control model based on BIM5D included 3D model construction, input of schedule and cost information, and association of schedule and cost information, as shown in **Figure 1**.

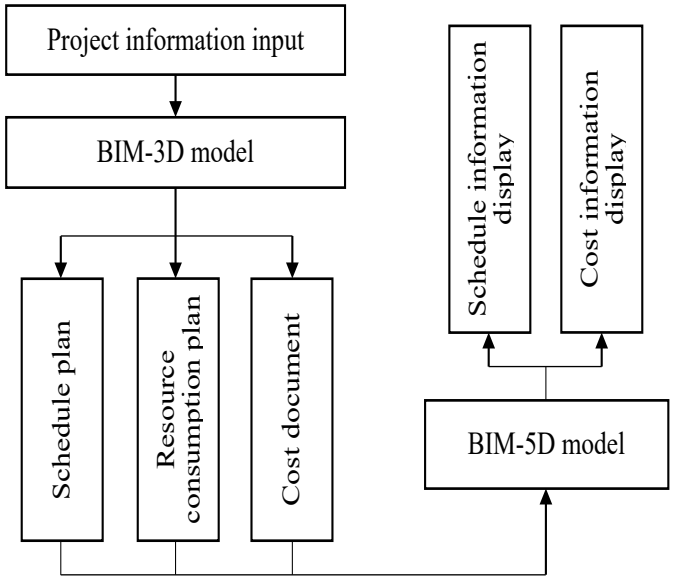

Figure 1. Modeling process of BIM5D Model for Qinghe Jincheng finished housing community

As shown in **Figure 1**, during the modeling of the 5D model, building a BIM3D model is the basic step. After establishing the BIM digital platform, project information is input to generate a physical model that displays the spatial structure and physical characteristics of the project in detail. Subsequently, after the 3D model is generated, schedule and cost parameters are input into the model, including detailed schedule plans, resource consumption plans, and project-related cost documents. This process needs to ensure the comprehensiveness and precision of the above data, covering the specific requirements of all construction stages [6]. In the 5D model, the schedule plan is mainly displayed through a timeline, allowing the project team to keep track of the start and end times of each construction link. The resource consumption plan lists the human, material, and equipment resources required at different stages. The cost documents provide the model with information on resource budgets and actual expenditures, enabling cost monitoring and adjustment throughout the entire lifecycle of the Qinghe Jincheng finished housing project.

4.2.2. Model information association

During the cost control phase supported by the BIM5D model, it is necessary to associate cost information with the model accurately. Firstly, a cost database system is introduced into the BIM3D model, which identifies the attributes of building components within the model and links them with the cost database. The cost data for each component, including material unit prices, labor costs, equipment usage fees, etc., is extracted in real-time from the cost database [7].

4.3. Dynamic cost control based on BIM5D

4.3.1. Cost deviation analysis

During the implementation of the later decoration engineering of the project houses, the entire cost deviation analysis phase based on BIM5D involves integrating design, construction progress, and actual cost data through the BIM5D platform for the Qinghe Jincheng finished housing project team. The design and construction data are provided by the BIM3D model, the construction progress data is taken from project, and the cost data comes from on-site collected financial data and financial databases. After completing data integration, the BIM5 model performs automated cost deviation detection by setting a benchmark budget and expected costs, comparing actual costs with budgeted costs during each project implementation, and calculating deviations in real-time. For example, the decoration engineering budget for the Qinghe Jincheng finished housing project is 6,850,000.00 yuan, of which the budget for the water and electricity renovation sub-project is 380,000.00 yuan, but the actual expenditure is 397,000.00 yuan. The BIM5D automatic detection mechanism immediately identifies a cost deviation of 17,000.00 yuan and visually displays it on the computer interface.

4.3.2. Cost performance analysis

Cost performance analysis evaluates the specific effectiveness of cost control from a holistic perspective, while predicting and optimizing future costs. The cost performance analysis process based on the BIM5D model includes benchmark indicator setting, data collection and deep analysis, simulation and prediction, and performance evaluation.

(1) Benchmark indicator setting

The Qinghe Jincheng project team establishes key cost performance indicators (cost efficiency indicators, schedule cost index) within the BIM software and uses these benchmarks as the basis for cost performance evaluation. For example, the CPI (Cost Performance Index) is calculated as CPI = EF/AC, where EF represents the cumulative earned value and AC represents the cumulative actual cost. If the calculation results show that CPI < 1.0 or the CPI index is gradually decreasing over time, it indicates insufficient cost control and timely adjustments are needed.

(2) Data collection and deep analysis

The project team automatically collects actual cost data and planned costs through the BIM5D platform. Based on data mining and analysis techniques, they conduct deep analysis on historical cost data to identify cost trends and anomalies. For instance, if it is found that labor costs show a sudden increase during a specific period of the decoration project, further investigation is needed to determine the specific reasons and influencing factors for the increase.

(3) Simulation and prediction

Time series models are used to predict future costs [8]. For example, if it is found during the decoration project that labor costs increase during winter due to an imbalance in worker supply and demand, the BIM5D model can predict the cost consumption trend for the next few construction stages through simulation, allowing the project team to take preventive measures ahead of time.

(4) Performance evaluation

Based on the results of cost performance evaluation, cost optimization strategies are developed. During the cost performance analysis of the Qinghe Jincheng finished housing project, the overall budget for the decoration engineering was 6,850,000.00 yuan. The BIM5D model detected a cost overrun of 170,000.00 yuan in the hydropower engineering, with actual expenditures reaching 397,000.00 yuan. After identifying this cost deviation issue, CPI calculations revealed that the deviation was due to overspending on concrete materials, with a CPI index of 0.65. In response, the project team re-evaluated the pricing of concrete suppliers and selected a more cost-effective supplier. By adjusting the material procurement strategy in a timely manner, they successfully brought the concrete cost within the budget range, and the CPI index rose back above 1.0.

4.3.3. Progress deviation analysis

The core of the progress deviation analysis for the Qinghe Jincheng completed housing project lies in identifying and addressing deviations during the construction process, ensuring that the project is completed within the established timeframe and controlling additional costs caused by delays. During project implementation, the BIM5D model integrates project plans, cost budgets, and real-time construction data. Each work package is accompanied by a detailed progress plan. The BIM5D model combines progress data extracted from the project with actual data obtained from on-site monitoring equipment (such as drones and sensors) and compares it with the progress plan data within the model, automatically generating a progress deviation report.

For example, during the construction of the Qinghe Jincheng completed housing project, the project team used drones to regularly capture high-precision images of the construction site during the main construction phase. Through image recognition technology, the actual construction points were analyzed and compared with the planned progress in the BIM5D model. When the project plan reached its 20th week, the main structure of Building 1# should have been 70% complete, but actual data showed only 67% completion. This progress deviation was detected by the BIM5D model, which immediately generated a progress deviation report. The project team then analyzed this report and determined that the deviation was caused by quality issues with the steel materials. The supplier had just changed, and transporting the materials took an additional two days, resulting in a delay.

4.3.4. Progress performance analysis

Progress performance analysis aims to evaluate construction efficiency and resource utilization, quickly identifying key factors that affect progress and cost. During project implementation, the BIM5D model compares the progress baseline with actual progress, generating an EVM (Earned Value Management) report to assess the Cost Performance Index (CPI) and Schedule Performance Index (SPI). This allows for the rapid identification of deviations between progress and cost. For instance, during the installation of water supply and drainage pipes in the Qinghe Jincheng completed housing project, the SPI value provided by the BIM5D model was below 1.0, indicating low progress efficiency and construction delays. By analyzing on-site and historical construction data, the project team discovered that some workers were unfamiliar with the new construction methods, leading to slow installation speeds and frequent errors, which increased rework costs [9].

4.3.5. Cost warning

For cost warnings in the Qinghe Jincheng project, the BIM5D model updates on-site construction data to the BIM platform in real-time through sensing devices and wireless networks, ensuring data freshness. Based on this, the BIM platform performs cross-analysis on multiple dimensions of cost data, such as material procurement and labor costs, during the project implementation phase, identifying potential cost overruns. Simultaneously, combining

preset cost thresholds for various dimensions and overall costs, the BIM model automatically activates a warning mechanism when cost deviations exceed the threshold, notifying project managers and relevant units via SMS, QQ messages, and emails.

4.4. Cost correction

The BIM5D model enables the generation of cost correction decision schemes for cost overruns. After receiving cost warning notifications, participating construction units can adjust their cost plans. The BIM5D model then simulates and analyzes the adjusted schemes, assessing the specific impact on costs and progress to ensure that the engineering team can select the optimal strategy [10].

5. Conclusion

Based on the BIM5D model cost control system studied above, the Qinghe Jincheng completed housing project has successfully achieved precise management and control of construction costs under the cost warning system based on the BIM5D model. This not only ensures the project's financial health but also promotes the transparent management of the construction process, significantly improving the project's overall efficiency and economic benefits. Construction engineering units can learn from the Qinghe Jincheng completed housing project's experience during the cost control phase of completed housing, strengthening the construction and application of the BIM5D model. This will comprehensively enhance the intelligence level of project team cost control, providing effective technical support for obtaining established economic benefits and preventing cost overruns.

Disclosure statement

The authors declare no conflict of interest.

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